PATENT
450111-03701

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

TITLE: RESOURCE ALLOCATION IN CDMA WIRELESS COMMUNICATION SYSTEMS

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Resource Allocation in CDMA Wireless Communication Systems

The present invention relates to resource allocation in code-division-multiple-access (CDMA) wireless communication systems, and in particular to the problem of assigning spreading codes to users under different multipath channel conditions.

CDMA is widely used in modern wireless communication systems. For example, one known variety of CDMA system [1] includes multiple base stations each defining a "cell", that is an area surrounding the base station in which transmissions from the base station may be received. Users are provided with mobile communications devices (e.g. mobile phones) which communicate with the base station of the cell in which they are located using CDMA signals transmitted in each direction ("downlink" to the mobile device, and "uplink" to the base station). The CDMA signals for a given user are generated using a spreading code for each user. Each spreading code varies at time increments called "chips" and has a period of N chips (a "symbol"). A signal bit is sent between each mobile device and the base station during each symbol.

In current systems, the spreading codes are assigned by a central resource management unit for each user. This may not be the optimal resource allocation strategy, especially when there is multipath propagation, illustrated in Fig. 1, in which a CDMA signal from a CDMA transmitter 1 (which may be one of a base station or a mobile receiver) is transmitted to a CDMA receiver 3 (which may be the other one of a base station or a mobile receiver) via different paths 5. The components of the multipath signal are added together at the receiving antenna 7. This addition can be constructive or destructive, i.e. the receiving signal amplitude can be larger or less than that of a single path signal.

If the signal bandwidth is larger than channel coherence bandwidth, the multipath delays will spread over many chip intervals. In this case, a specific receiver structure called a RAKE receiver may be appropriate [2]. The RAKE receiver makes use of the multipath signal energies at the symbol-level, i.e. it coherently adds the different delayed multipath signals after despreading each of them. Thus some signal gain is obtained.

A method has been proposed recently which dynamically assigns the spreading codes and delays of multiple users with the object of minimising the mutual cross-correlation among them in the receiver [3]. This method helps to avoid multiple access interference (MAI) which arises when a given user receives signals from multiple transmitters. However, the method can only be used in the uplink of a cellular CDMA system by a base station which knows all the spreading codes for all users. Also, the algorithm to determine the spreading codes is complex and can only be implemented recursively. Another drawback of the method is if the number of users in a cell is low, the benefit of the method decreases.

The present invention aims to provide a new and useful method for assigning spreading codes in a CDMA communication system. This general problem has relevance for many different fields including wireless cellular communications, satellite communications, local area networks, personal area networks and wireless local loops. One of its major applications is to assign spreading codes of a CDMA system.

In general terms, the present invention proposes matching the spreading code and the multipath channel of each receiver, so that the signal energies of different paths add constructively instead of destructively at the antenna of the receiver. This may make it possible to make full use of the multipath signal energies. The benefit of the proposed method is most evident for a frequency-

selective channel in which the multipath delay profile spreads over many chip intervals.

Important advantages of a preferred embodiment of the invention compared to the known systems described above are that: (1) it makes fuller use of the multipath signal energies than does the RAKE receiver [2]; (2) by selecting appropriate spreading codes, the multipath channel itself delays and modifies the signals and makes most of the mulitpath components contribute constructively to the sum of the received signal; (3) as input data the embodiment employs only channel estimation information, and the auto-correlation functions of the spreading codes; (4) the algorithm to find the best spreading codes may be very simple; and (5) it can be used in both ends of a radio link (for cellular communications, both uplink and downlink).

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Figure 1 shows a multipath channel between a transmitter and a receiver; and

Figure 2 is a block diagram of a receiver which is an embodiment of the present invention.

A procedure according to the invention for dynamic assignment of spreading codes, which may be performed by the CDMA receiver 3 of Fig. 1, will be explained with reference to Figure 2.

(1) Signals received by the aerial 7 are CDMA signals which use spreading codes to spread the symbols of the transmitted data. These signals are propagated over a multipath channel where the multipath delays are longer than at least one chip's period. The received signal is input to circuitry shown in Fig. 2, in which it is sent to a channel estimation or channel prediction unit

9, a RAKE receiver unit 11 as described in [2], and a unit 13 which informs the RAKE receiver unit 11 of changes in the receiver's spreading code.

(2) In the unit 9, the parameters of the multipath propagating channel to the receiver are estimated in real-time by a method which may either be training-based (i.e. if the aerial 7 receives signals encoding known data) or blind. Two such known methods are the training-based maximum-likelihood algorithm or blind-based moment algorithm. Alternatively, unit 9 may predict the channel parameters based on other information.

The channel parameters are here denoted by a set of L complex channel coefficients c(j), where L is the maximum delay expressed as a number of chip periods. Specifically, the multipath channel may be modelled as a tap-delay-line structure with complex coefficients: c(0), c(1),..., c(L-1).

(3). The unit 9 sends the estimated channel parameters to a spreading code selection unit 15 where the spreading codes with better performance are selected based on the channel parameters and the auto-correlation functions of all the available spreading codes.

Suppose that the invention is used to select a spreading code from K possibilities, labelled by $k = 1,\ldots,K$. For a specific kind of spreading code (for example Gold codes or Walsh codes) of a specific code length, it is easy to calculate the auto-correlation function r_s (k, i) of the k^{th} code at the i^{th} delay.

The best code over the multipath channel may be determined as the k given by:

$$k = \arg \max_{k} \left\{ m(k) = \mathrm{Re}\left[\sum_{j=0}^{L-1} c^{*}(j) \sum_{i=0}^{L-1} c(i)\; r_s(k, i-j)\right] \right\} \qquad (1)$$

where * represents complex conjugate, and $\arg \max_{k} f(k)$ means the value of k which maximises any function *f(k)*. Note that for many known spreading codes (e.g. Gold and Walsh codes) the contents of the square bracket in (1) are real in any case, and thus the operation Re (i.e. taking the real part of the square bracket) does not change the result.

Note that we have derived the expression for *m(k)* in (1) from the RAKE receiver structure. The signal received in one finger of the RAKE receiver after correlation may be expressed as $\sum_{i=0}^{L-1} c(i) r_s(k,i)$, and each finger's contribution to the RAKE receiver output may be represented by one of the $c^*(j)\sum_{i=0}^{L-1} c(i) r_s(k,i-j)$, so that m(k) represents the overall RAKE receiver output. Thus, if the RAKE receiver 11 is replaced by a receiver which is not a RAKE receiver, *m(k)* in equation (1) is preferably be modified appropriately.

(4). Unit 15 instructs a code request generation unit 17 to send a signal identifying the spreading code k with best performance to a resource allocating centre. In the case of an embodiment which is a cellular wireless telephone system, this centre is preferably in the base station. So, if the method according to the invention is being carried out by a CDMA receiver which is a mobile phone, then a signal will have to be transmitted to the base station, whereas if the CDMA receiver which is performing the invention is the base station itself, no transmission is necessary. Alternatively, one resource allocating centre may be shared by many base stations.

The resource allocating centre determines whether the requested code is available. If the required code is available and any other conditions are satisfied (for example, the priority of the radio link is the highest), the requested code is used to spread the symbols of that link. Note that the spreading codes used both uplink and downlink are preferably different.

Actually, if frequency division duplex is used, the uplink and downlink channels are also different.

(5). If the required spreading code is not available, the resource allocating centre will send some information to the receiver which issued that request. The code-selection block 15, selects the next best spreading code, and instructs the unit 17 to transmit a signal identifying that code.

(6). Repeat steps (4) and (5) until a spreading code is finally determined.

Figure 2 includes a unit 13 which notifies the unit 11 of changes in the spreading code. There are various ways in which unit 11 may operate. If the resource allocating centre is present in the receiver (e.g. in a cellular communication system, if the receiver is a base station containing a resource allocating centre) an electric connection can be provided from the resource allocating centre to the unit 13. In cellular comunications systems, the spreading codes determined by a base station may be notified to the mobile phones by a common communication channel which is shared by all users within the cell. However, alternatively, the code information may be transmitted along the same communication channel to which it relates using the previous spreading code. In a further alternative, unit 13 may not receive a message that a new code has been assigned, but actually deduce it from the CDMA signal.

(7). The RAKE receiver 11 despreads the received signals using the channel estimation from the unit 9 and the spreading code notified by the unit 13.

The proposed method can be used at either or both ends of the radio links of a CDMA communication system. For example, in a cellular wireless communication system, the channel can be either of a downlink and a uplink channel. The spreading codes can be any kind which have non-uniform

sidelobes at their auto-correlation functions, for example the Gold codes or Walsh codes (Orthogonal Variable Spreading Factor (OVSP) codes).

References

The disclosure of the following documents is incorporated herein by reference.

[1]. K.S. Gilhousen et al. "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System", U.S. Patent No. 5,103,459.

[2] J. G. Proakis, "Digital Communications", 3rd edition, McGraw-Hill, 1995, pp 797 – 806.

[3]. Jiunn-Tsair Chen, C.B. Papadias and G. J. Foschini "Dynamic Signature Assignment for Direct-Secquence CDMA Systems", IEEE Communication Letters, Vol. 4, No. 6, 2000.

[4]. A. Duel Hallen, et al "Long-Range Prediction of Fading Signals", IEEE Signal Processing Magazine, Vol. 17, No. 3, May 2000.